

## **Appendix I: Very High Temperature Reactor**

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# Very High Temperature Reactor (VHTR)

## 1 INTRODUCTION AND BACKGROUND

The VHTR is the nearest term, of the six reference Generation IV reactor concepts, for nuclear hydrogen production. The basic technology for the VHTR has been established in former high temperature gas-cooled reactor plants (DRAGON, Peach Bottom, AVR, THTR, Fort St. Vrain). In addition, the technologies for the VHTR are being advanced in the GT-MHR project and the PBR and PMR International Near-Term Deployment projects. Furthermore, the Japanese HTTR and Chinese HTR-10 projects are demonstrating the feasibility of some of the planned VHTR components and materials. (The HTTR is expected to reach a maximum coolant outlet temperature of 950°C in 2003.) Therefore, this project is focused on building a demonstration plant, rather than simply confirming the basic feasibility of the concept.

The goal of the Next Generation Nuclear Plant (NGNP) is to deploy a full-scale demonstration Generation IV VHTR reactor at the INL, capable of producing low cost hydrogen by 2017. The significant advantages of high fuel burn-up, passive safety, low O&M cost, and potential modular construction were evident in the Generation IV submitted concepts. The final design of the demonstration NGNP will be constrained to maintain these advantages. It is envisioned that a deliberate and focused program of R&D in support of a disciplined design and construction project could make a demonstration VHTR, with a flexible hydrogen production system, operational by the 2017 timeframe.

One or more basic processes will use the heat from the high temperature helium coolant to produce hydrogen. The first process is the thermo-chemical splitting of water into hydrogen and oxygen. The primary thermo-chemical candidate is the iodine-sulfur (IS) process. A second promising process is thermally assisted electrolysis. The high efficiency Brayton cycle enabled by the NGNP may be used to generate the hydrogen from water by electrolysis. The efficiency of this process can be substantially improved by heating the water to high temperature steam before applying electrolysis. The waste heat from the pre-cooler and inter-cooler of the Brayton cycle, therefore, can be used to further improve the efficiency of hydrogen production.

The NGNP and Generation IV program is sponsored by the DOE Office of Nuclear Energy, Science and Technology and is managed under the Nuclear Energy Program's Advanced Nuclear Research (NE-20). The NGNP is currently in the Project Initiation Phase and not considered a DOE Project. It is currently managed under the Integrated Generation IV Program/Advanced Fuel Cycle Initiative Structure and will become established as an independent project under the Generation IV Program of NE-20. The schedule for the NGNP project is illustrated in Figure 1-1. A slightly more detailed logic diagram with time line showing major interfaces and dependencies among major project activities can also be found in Figure 8-1. See the *Draft Next Generation Nuclear Plant Program Management Plan (at the Project Initiation Phase)*, INEEL/EXT-03-01326,

Rev. 0, October 2003, for more information and details on the planning and Management of the NGNP.

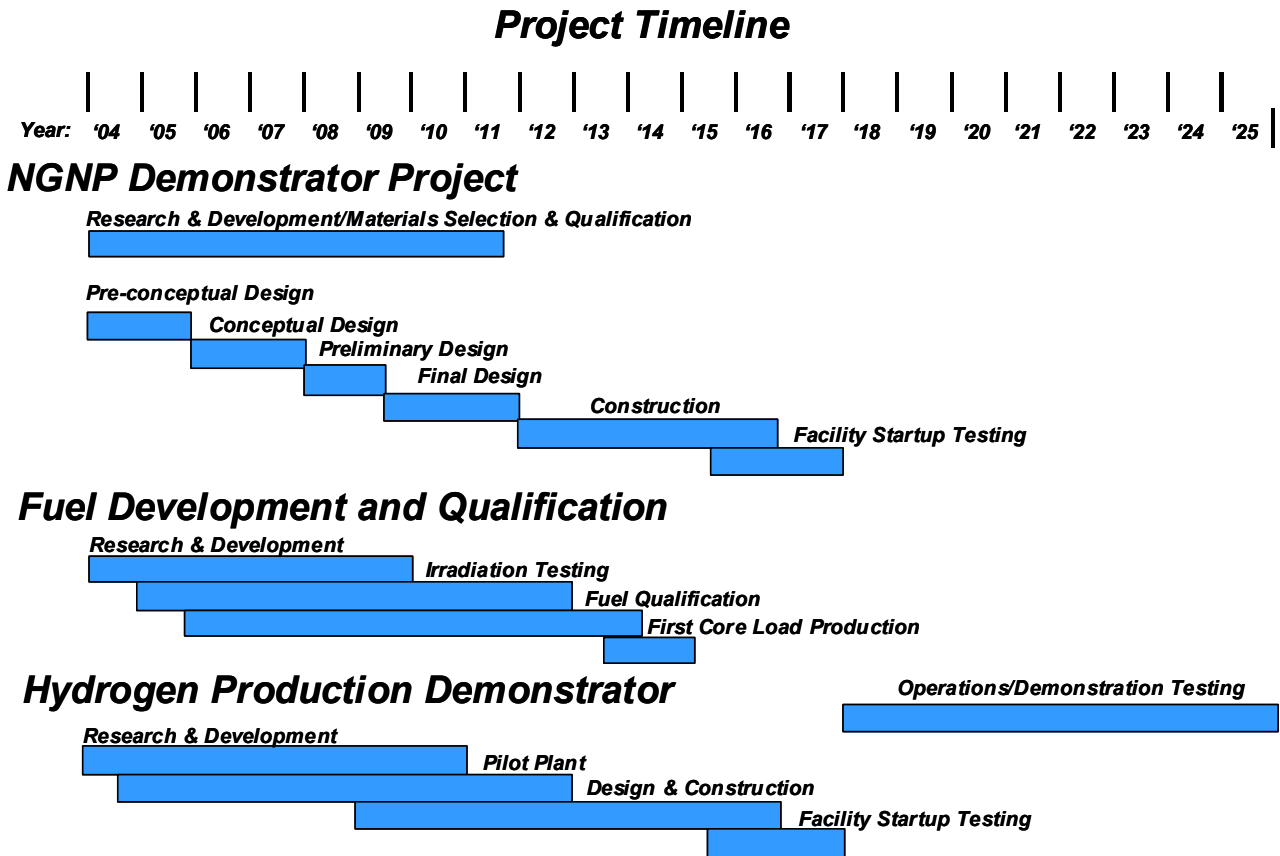


Figure 1-1. – Project Timeline

## 2 NGNP PROJECT PLANNING

The NGNP design, construction, startup, and turnover for operation requires a management process prescribed by DOE Order 413.3, *Project Management for the Acquisition of Capital Assets*, unless exempted by the Secretary of Energy. The NGNP is presently in the Project Initiation Phase and not officially considered a DOE project until the mission need statement is developed and approved by the Deputy Secretary of Energy. A formal Program Plan is normally prepared after Mission Need is established, and a Preliminary Project Execution Plan (PEP) is normally prepared during the Conceptual Design Phase, after the mission need has been approved, acquisition strategy formulated, and requirements have been developed. However, to establish the vision for the NGNP and facilitate the pre-conceptual planning described in this document, assumptions have been made that the NGNP mission need is valid and a new material asset, consisting of an advanced gas-cooled nuclear reactor and hydrogen production facility, will be built. These and other assumptions, which are listed further in this document, will either be validated or changed as the proposed project progresses through the phases of Project Initiation/Planning, Project Definition, and Preliminary Design. Future decisions concerning mission need, requirements, and acquisition strategy will be made as the project matures.

### 3 MISSION STATEMENT

DOE's primary mission for the NGNP is to demonstrate nuclear reactor-assisted cogeneration of electricity and hydrogen while meeting the Generation IV goals for safety and reliability, sustainability, proliferation resistance and physical security, and economics. As a demonstration project, NGNP design, development, and deployment will aid in revitalizing the nuclear energy infrastructure vital to support the growing demand for electricity while providing hydrogen needed to fuel emissions-free vehicles. Thus, the NGNP will reenergize the domestic nuclear and transportation industries by:

- Demonstrating advanced power and hydrogen generation technologies
- Demonstrating the safety capabilities of the NGNP concept
- Achieving NRC licensing of a next-generation reactor
- Resolving and sharing technology risks to restart the United States' energy infrastructure
- Eliminating 'first-of-a-kind' concerns / issues using a risk-based methodology
- Demonstrating an operable design that ensures natural, passive safety
- Providing high-efficiency electricity and process heat for demonstrating and optimizing hydrogen production
- Supporting the development and testing of prototype hydrogen infrastructures necessary for new transportation energy sources and other existing and new industrial hydrogen applications.

**NGNP Mission:** to demonstrate nuclear reactor assisted cogeneration of electricity and hydrogen while meeting the Generation IV goals for safety and reliability, sustainability, proliferation resistance and physical security

### 4 HIGH-LEVEL OBJECTIVES

High-level NGNP Program objectives support both the NGNP mission and the DOE vision as follows:

1. Develop and demonstrate a commercial-scale, prototype Very High Temperature Reactor that is economically competitive and passively safe while meeting the other high-level Generation IV goals and objectives
2. Develop and demonstrate full-scale, high-efficiency power conversion using a Brayton Cycle
3. Obtain an NRC License for reactor construction and operation to provide a basis for future performance-based, risk-informed licensing of a next-generation reactor for the power industry
4. Develop and demonstrate approximately 1/10<sup>th</sup> scale production of hydrogen
5. Include features for extended testing that will demonstrate the exceptional safety capabilities of advanced gas-cooled reactors
6. Support and enable demonstration of energy products and processes that will develop, test, and prototype hydrogen infrastructures necessary for new transportation energy sources and other existing and new industrial hydrogen applications

7. Provide a mechanism to revitalize the U.S. nuclear industry infrastructure and energize the U.S. nuclear utility industry by engaging industrial partners in resolving technology risks and eliminating first-of-a-kind concerns with validation of next-generation reactors.

The graphic in Figure 4-1 below summarized the high-level objectives and the functions and requirements of the NGNP. The high-level functions and requirements have been initially defined in, *Next Generation Nuclear Plant - High-Level Functions and Requirements*, INEEL/EXT-03-01163, September 2003.

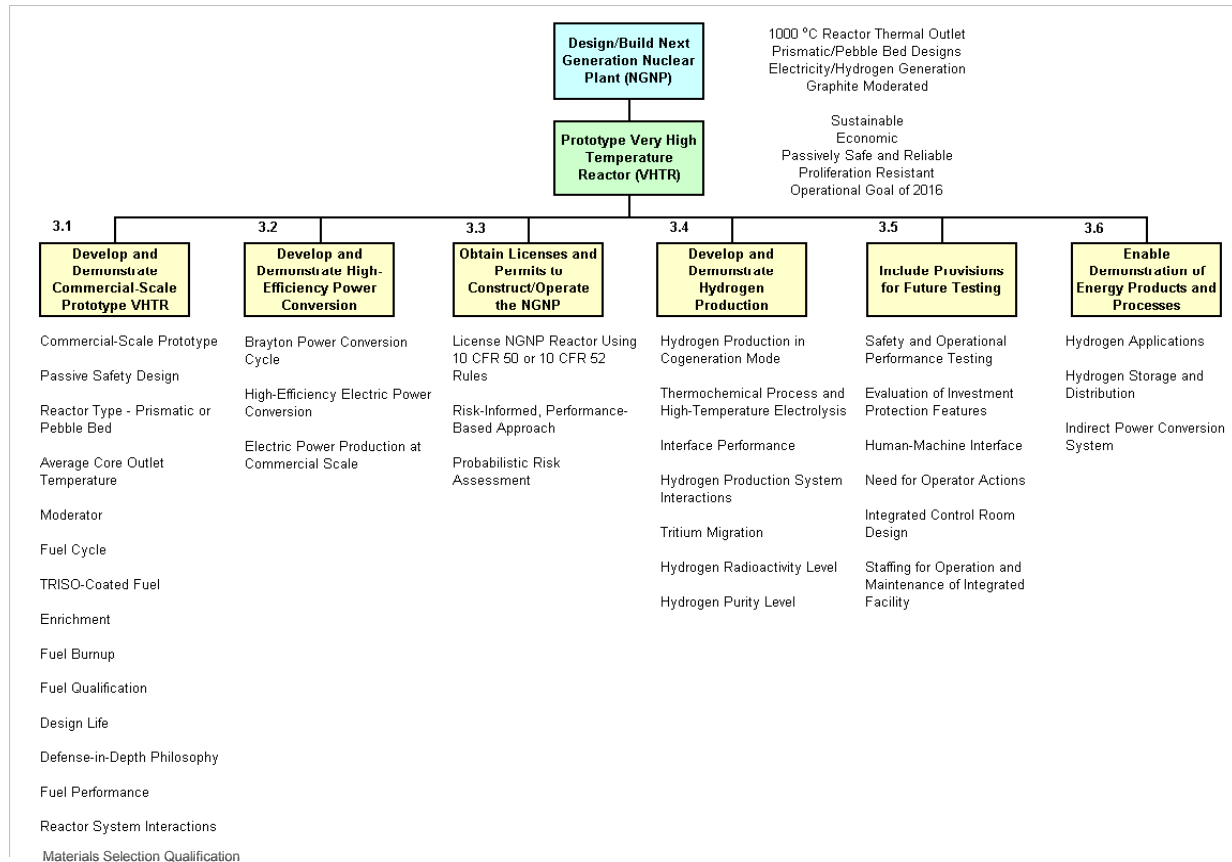


Figure 4-1. – High-Level Requirements

## 5 NGNP DESCRIPTION

The NGNP Generation IV reference concept is a helium-cooled, graphite moderated, thermal neutron spectrum reactor with an outlet temperature of 1000°C or higher. Although final selection of the reactor core technology will be made during the Initiation Phase, the reactor core is envisioned to be a prismatic graphite block gas cooled concept (or potentially a pebble bed reactor). The NGNP will produce both electricity and hydrogen. An intermediate heat exchanger (IHX) will transfer the heat to a hydrogen production technology test-bed. The gas turbine may obtain heat directly from the helium coolant outlet from the reactor. This will require that an IHX and primary gas circulator be located in an adjoining power conversion vessel. Figure 5-1 provides a conceptual schematic of the NGNP.

The reactor thermal power (400 - 600 MWt) and core configuration will be designed to assure passive decay heat removal without fuel damage during accidents. The fuel cycle will be a once-through, very high burn-up, low-enriched uranium fuel cycle.

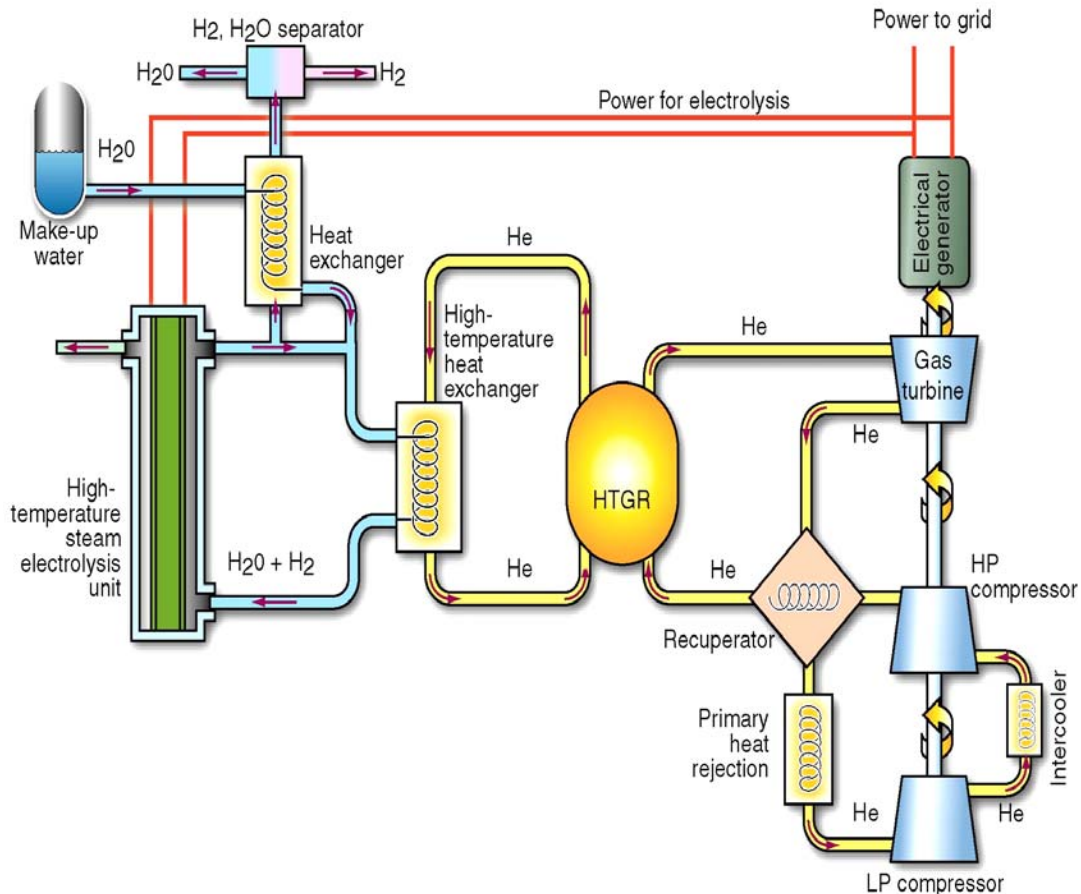


Figure 5-1. NGNP Conceptual Schematic Showing Power Generation and Hydrogen Production

The basic technology for the NGNP has been established in former high temperature gas-cooled reactor plants (DRAGON [England], Peach Bottom Unit 1 [U.S.], Arbeitsgemeinschaft Versuchsreaktor [Germany], Thorium Hochtemperatur Reaktor [Germany], Fort St. Vrain [Colorado]). In addition, the technologies for the NGNP are being advanced in the Gas Turbine-Modular Helium Reactor (GT-MHR) Project and the pebble bed and prismatic reactor (PBR and PMR) International Near-Term Deployment projects. Furthermore, the Japanese HTTR and Chinese HTR-10 projects are scaled reactors demonstrating the feasibility of some of the planned NGNP components and materials. (The HTTR is expected to reach a maximum coolant outlet temperature of 950°C in 2003.) Therefore, the NGNP will advance the technology to 1000°C coolant outlet temperature, along with advanced material, fuel, power conversion, and heat exchanger requirements, by demonstrating a commercial scale reactor, rather than simply confirming the basic feasibility of the concept.

One or more processes will use the heat from the high temperature helium coolant to produce hydrogen. The first process of interest is the thermo-chemical splitting of water into hydrogen and oxygen. The primary candidate thermo-chemical process is the sulfur-iodine (IS) process. The second process of interest is thermally assisted electrolysis of water. The high efficiency Brayton cycle enabled by the NGNP may be used to generate the hydrogen from water by electrolysis. The efficiency of this process can be substantially improved by heating the water to high temperature steam before applying electrolysis. The waste heat from the pre-cooler and inter-cooler of the Brayton cycle, therefore, can be used to further improve the efficiency of hydrogen production. The NGNP is the nearest term of the six reference Generation IV Roadmap reactor concepts. It is envisioned that a deliberate and focused program of R&D in support of a disciplined design and construction project could make a demonstration NGNP, with a hydrogen production system, operational as early as 2017. The significant advantages of high fuel burn-up, passive safety, low O&M cost, and potential modular construction were evident in the Generation IV submitted concepts. The final design of the demonstration NGNP will be constrained to maintain these advantages.

Passive safety is achieved by designing for a core cool-down during a postulated long-term depressurized loss-of-forced convection accident that limits the peak fuel temperatures to 1600°C. This is accomplished by conducting the decay heat radially through the core and pressure vessel, and then radiating it to passively cooled panels in the reactor cavity building. There is also a non-safety shutdown cooling system (SCS) used only to remove decay heat during normal shutdowns, such as during refueling operations. In the representative design the entire reactor confinement structure is underground. The reactor vessel and power conversion vessel are side-by-side and connected by a cross-vessel that is deliberately made as short as possible to minimize thermal expansion differences between the two large vessels. Within the cross-vessel the reactor inlet gas flows in an annular duct along the inside surface of the cross vessel to the reactor inlet. The core exit hot gas flows in a central duct along the centerline of the cross-vessel to the intermediate heat exchanger. Other design configurations will be considered during the conceptual design process.

The Generation IV representative case assumption is that the reactor core will be of a prismatic type design, however the pebble bed reactor technology is also under consideration. Under the representative assumption, the core consists of graphite blocks with an annular-fueled region surrounded by reflector elements. The fuel is TRISO coated fuel particles embedded in graphite compacts and placed in graphite prismatic blocks. The center of the core is a non-fueled graphite reflector. Normal operating maximum fuel temperatures do not exceed 1250°C. The reflectors mitigate the high-energy fluxes, and boron pins placed in the outer reaches of the reflectors reduce thermal neutron fluxes on the metallic internal structures and reactor vessel.

From the cross-vessel, the reactor helium coolant inlet (~450°C and ~7 Mpa) then flows upward in the annulus between the vessel and the metallic core barrel surrounding the side reflector. The coolant then enters the upper plenum region volume, which contains

the lower parts of the control rod housings. The reactor pressure vessel upper head is protected by fibrous" insulation blankets. The insulation protects the head from hot plumes that could occur during a pressurized loss-of-forced-convection accident. The inlet flow then passes down through the core's upper support plates and then flows primarily into the coolant channel holes in the fuel elements, into the lower plenum, and then into the hot duct. From the hot duct the coolant will go to energy conversion applications such as the direct drive "Brayton Cycle" turbine driven electrical generator or to an intermediate loop heat exchanger for heat driven application such as hydrogen production.

The result of this program is the demonstration a NRC licensed full-scale prototype, (estimated at approximately 600 MW(t)) helium-cooled reactor (approximately 300 MW(e)) using a "Brayton Cycle" turbine driven electrical generator. The reactor will also provide nuclear heat through an intermediate heat exchanger for the 1/10<sup>th</sup> scale demonstration of hydrogen production. The hydrogen production engineering demonstration facility is currently covered in separate data sheets as a separate but integrated project.

## **6 NGNP PROJECT MANAGEMENT ORGANIZATION**

The NGNP Project will be structured as an international public-private partnership under a common NGNP management structure. The project is sponsored by the DOE Office of Nuclear Energy, Science and Technology and is managed under the Nuclear Energy Program's Advanced Nuclear Research (NE-20). Prior to Critical Decision-0 (CD-0), Approval of Mission Need, the work under the NGNP will continue to be managed under the Integrated Generation IV Program/Advanced Fuel Cycle Initiative Structure. Once CD-0 is approved and the NGNP is established as a project, it is assumed that the project will be managed under DOE O 413.3, "*Project Management for the Acquisition of Capital Assets.*" In which case the project will be organized under a Federal Project Director and integrated project team. Day to day project management functions will be delegated to the M&O Contractor of the INL, NE's lead laboratory.

To accomplish this an INL NGNP Project Office will be established. The INL NGNP Project Office will be responsible for coordination, directing, and managing participating partners, including but not limited to: Industry and international partners, other DOE laboratories and universities. The assumed roles and responsibilities of the INL M&O Contractor are:

- Serve as "Owner and Operator for the NGNP
- Provide Project Management and Technical Integration of R&D
- Conduct of major R&D elements
- Startup and project acceptance
- NRC Licensee
- Operator for future development activities
- Owner Project Integration for DOE
- Project Support (Schedule, Project controls, Records, RM, Configuration Management, etc.)

The schematic in figure 6-1 below represents the management arrangement of various partners and members of the NGNP Team. Solid lines represent flow of responsibility and the dotted lines indicate where communication, coordination, and support are required.

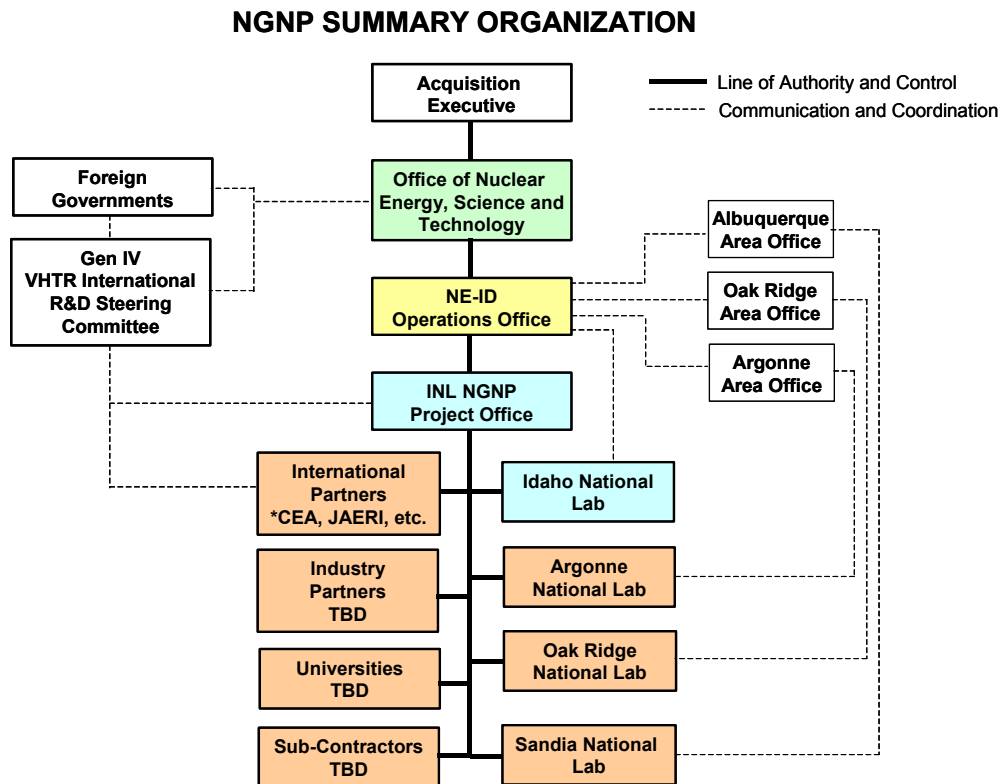


Figure 6-1. NGNP Summary Organization

International partners, with DOE, are expected to include the Generation IV International Forum countries such as France, Japan, Great Britain, South Korea, and others who have an interest in participating financially and collaborating on research and development activities, concept definition, and analysis that can also be used to in the development of a VHTR system in both the U.S., and their own country. Industry partners will include U.S. power generation companies whose role will be to provide current and practical program input to assure that the prototype nuclear plant will be licensable and representative of future marketable reactor system designs. These companies will also support design, permitting, licensing, construction, startup, and operation activities. Determination of specific partners will be made during the project initiation and Conceptual Design Phases and documented in the formal Acquisition Strategy by or before CD-1.

Support from other DOE Labs, universities, international, industry and architectural engineering subcontractors will be obtained where their expertise can benefit the NGNP. It is important that all program related budget and work by these contributors be

controlled through the NGNP Project in order to maintain a single point of control. The primary interfaces occur both among the DOE offices and among the laboratory participants. The simplest possible interface mechanisms, including; inter-lab work agreements; work package responsibility assignment; and subcontracts with specific project driven scopes, schedules and budgets, based on prior experience of all the participants having worked together on other activities and projects. The INL NGNP Project Office will control and integrate activities and contributions of all participants.

## **6.1 International Partnerships**

International partnerships will be formed around a limited number of key technology needs. Coordination of the international partnerships will be aligned through the Generation IV International Forum and GIF R&D Steering Committees by selection of specific R&D projects as needs are identified. Funding for the R&D effort will come from the GIF country. Intellectual property will remain with the performing country. Sharing with interested GIF countries on specific R&D findings will be encouraged through formal agreement with the GIF country. The VHTR GIF R&D Steering Committee will coordinate efforts on behalf of the GIF.

## **6.2 Industry Partnerships**

Industry partnerships will be conducted through formal competitive performance based contracts. The contracts will include provisions for cost sharing. Mechanisms within the subcontracts will provide protection of intellectual property rights. If the industry partners participate beyond R&D activities and into the implementation phase of competitive design and construction contracts, provisions shall be included for equitable consideration of use of the property rights. Industry participation will also be gained through the Industry Advisory Group.

## **6.3 Partnering DOE Laboratories**

The Federal Project Director will establish a Memorandum of Agreement through NE-ID and the local DOE office for each participating laboratory. This agreement will define the roles, responsibilities, and expectations of the local offices needed to support the NGNP Project. The MOA will provide the framework for DOE field Office oversight and coordination of the partner laboratories' efforts to support the NGNP Project work. All funding for this work is provided by NE-HQ, through NE-ID to INL for execution of the NGNP. Subsequent funds transferred from INL to the participant laboratories are processed through the host DOE offices.

Each laboratory will be responsible for delivering specific products and deliverables necessary to complete the NGNP. Each laboratory will prepare approved execution plans, for performing their assigned work, incorporating the requirements of the execution plan above them in the document hierarchy. A Site Technical Lead will be assigned at each partnering laboratory where responsibilities for activities are focused at a single working level point of contact. The person serving as the point of contact will

report to the INL NGNP Project Manager on work activities supporting the NGNP. The Site Technical Lead will keep the Program informed of activities at his/her site and will gain overall program information through participation in the semiannual NGNP Project reviews. As planning progresses and the Work Breakdown Structure is finalized, the work will be assigned as discrete pieces of work as broken down into work packages in the WBS. A work package manager will be assigned responsibility for each WBS work package.

#### **6.4 Universities**

A goal of significant importance for the NGNP is to stimulate university nuclear R&D programs. Therefore the use of universities to support the NGNP R&D work is essential. Partnerships with universities will be conducted through formal sub-contracts. Mechanisms within the subcontracts will provide protection of intellectual property rights. One of the goals of university partnerships is to foster and stimulate student research and development work.

### **7 DESIGN AND CONSTRUCTION**

Ultimate responsibility for the acquisition of the project tasks lies with the DOE Acquisition Executive. Implementation responsibility lies with the M&O Procurement Director, and is delegated to the M&O Procurement Agent, as applicable. As such, DOE shall acquire, design, construct, and operate the NGNP through effective use of performance-based contracting techniques. Efforts will be made to encourage participation of females, minorities, and small/disadvantaged businesses (SDB) in execution of the NGNP.

#### **7.1 Prime Contracts**

It is assumed that the DOE is acquiring design, construction and operation of the NGNP through the M&O contractor responsible for the INL, yet to be determined through an ongoing site M&O contracting process. This contract is administered by NE-ID with authority for NGNP activities delegated to the DOE Program Director. Appropriate performance measures will be maintained in the M&O contract to promote effective management and completion of the NGNP. Similarly, working through the DOE site offices at the collaborating laboratories, appropriate performance measures will be incorporated into those M&O contracts.

Contracts for Preliminary and Final Design, and Construction will be handled through prime contracts administered under DOE. The exact strategy is still to be determined, but for planning purposes it is assumed that the contracts will be performance based design/build contract. The design and construction may or may not be broken into separate contracts, depending on the final acquisition strategy. The M&O contractor, as operator, will provide project management support as delegated, technical integration, direction and review for R&D, design, construction and startup/acceptance. The M&O contractor, as the operator, will also be the licensee.

## 7.2 Subcontractor(s)

To the extent possible, INL NGNP Program will endeavor to apply performance-based and fixed-priced contracting concepts for executing the project. Generally fixed price type contracts are used when requirements are well defined. Therefore during the early stages of the project, the Pre-Conceptual Engineering Studies and Conceptual Design contracts will be performance based cost reimbursable type contracts. Standard practice will be for INL NGNP and its subcontractors to have available budget authority to cover, at a minimum, the first increment of work (first year, first major deliverable, contract base period, etc.) to be performed under the sub-contract before initiating the procurement process. Exceptions to this standard practice, such as initiating procurement of the Architect- Engineer/Construction Manager (AE/CM) before line item project start, will be addressed on a case-by-case basis.

## 8 RESEARCH & DEVELOPMENT STRATEGY

Research and development for the NGNP program must be project driven and will follow the prerequisite of completing a point design and preconceptual engineering studies to evaluate and identify the bounding operational conditions and parameters (temperatures, pressures, radiation level, etc.) that will determine technical and functional requirements. These technical and functional requirements provide the bases for material requirements, fuel requirements and etc., which will focus and identify specific R&D needed to support the project.

The NGNP R&D program consists of five major areas. To facilitate integration into the NGNP R&D program activities and collaboration with GIF international partners, the five categories follow those established through the GIF VHTR R&D Steering Committee. The Nuclear Hydrogen Engineering Scale Production Project is currently managed as a separate project, however a high degree of interface, integration and coordination will be required between the reactor and the hydrogen plant. Therefore it is assumed that the two should be managed together and information on the R&D for hydrogen has been included in this appendix for reference. All R&D areas address crucial feasibility and performance issues and are as follows:

- System Design & Evaluation and Safety & Integration, now also called Design Methods and Evaluation – Definition of design methods, neutronic and thermal hydraulic models to determine operating temperatures and parameters while maintaining passive safety requirements, and other safety issues such as coupling nuclear systems and hydrogen production.
- Fuel Development and Qualification – Development of advanced coated fuel particles with adequate very high temperature potential.
- Materials and Components – Selection of structural materials for the reactor and for the Sulfur Iodine (S-I) process, development of crucial components such as the intermediate heat exchanger between the reactor and the S-I process, and demonstration of adequate performance in order to qualify the reactor materials under commercial standards and NRC regulations.

- Hydrogen Production Technologies – Development and optimization of the S-I hydrogen generation process or alternate processes, definition and validation of the reactor/process coupling approach
- High Performance Helium Turbine – Development of high performance helium turbine and other crucial components of Brayton conversion systems, and performance optimization of the balance of plant.

Each area of R&D will be managed under R&D program plans and Quality Assurance Plans developed for each of the areas identified above. The top-level R&D and Quality Assurance plans will be developed, maintained and controlled at the INL NGNP Project level. R&D program plans and Quality Assurance Plans will also be developed, by partnering laboratories and contributors, that tier from the top level INL NGNP R&D and Quality Assurance plans and those lower tier plans shall include all requirements of the plans above them in the document hierarchy. The Fuel Development Program Plan, the Materials Selection and Qualification Program Plan, and the Hydrogen R&D Plan have been developed. The System Design and Evaluation and Safety & Integration Plan will be developed during FY-04 and the High Performance Helium Turbine Development Plan will be developed later during the Project Initiation Phase.

There will be significant interaction and schedule dependencies between NGNP design, R&D, environmental permitting and NRC licensing, fuel development, and the Nuclear Hydrogen Engineering Demonstration Production Project. This will require that a project management structure be put into place early in the project in order to ensure proper technical, schedule, and cost integration takes place. The dependencies and interfaces between the major project activities are shown at a very high-level in Figure 6-1. System Design and Safety Integration R&D activities have not been included until planning is performed in FY-04.

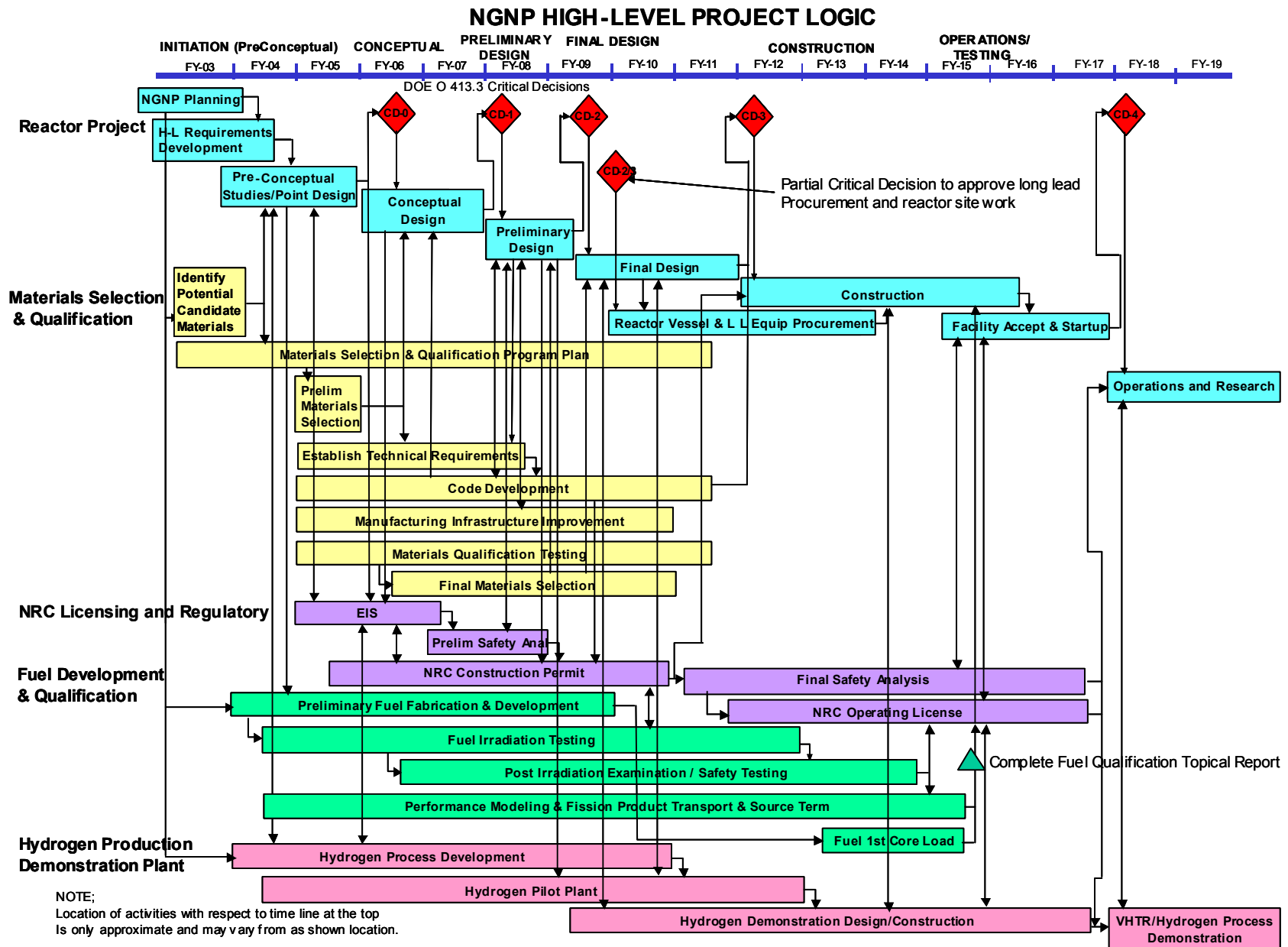


Figure 8-1. – NGNP High-Level Project Logic

## **9 SYSTEM DESIGN / SAFETY & INTEGRATION**

The system design, system safety analyses, and the integration of these activities are centered on the use of analytical tools that are sufficiently quality-assured and accepted by industry to perform the required tasks. The degree that the analytical tools are validated & verified (V&V) prescribes the work that can be successfully performed, e.g., pre-conceptual design, final design, license submittal, etc. Rapid and successful completion of this work is essential not only for performing meaningful design calculations but also acceptable licensing calculations. The development of the NGNP requires extensive analyses for performing the following:

- Reactor core and primary system design analyses
- Reactor safety system design analyses
- Plant design analyses
- Economic analyses
- Safety & licensing analyses
- Others—including human factors, PRA, etc.

### **9.1 Systems Design & Licensing Tools**

The tools required to perform pre-conceptual design, final design, and licensing calculations consist of thermal-hydraulics software, computational fluid dynamics (CFD) software, neutronics software, and mechanical assessment software. Used together these tools will give a complete evaluation of the system behavior (peak material temperatures, core damage, peak fluid temperatures at turbine inlet, plant efficiency, etc). Although the tools needed to perform these functions exist they must be certified to show that they are capable of calculating the desired system behavior, viz, transients, steady-state conditions, etc. Consequently, the steps in producing certified tools are:

1. Determine the key phenomena for the reactor and balance-of-plant.
2. The operational envelope of the limiting conditions and limiting processes must be determined.
3. The system design and licensing tools must be either validated at the conditions (item 2) for the key phenomena (item 1) by comparing their predicted behavior against data or by extracting from the literature documents which contain results that demonstrate the tools are capable of modeling the desired phenomena.
4. If the tools are shown to be incapable of matching the data or of predicting the phenomena properly then experts must determine whether the tools require additional development or may be used in their present state given their known biases or abnormalities are sufficiently known to enable “safe” calculations to be made.
5. If tool development is undertaken, then item 3 must be performed again to confirm the tools capability to model the key phenomena.

6. Following completion of items 1 through 5, design and licensing calculations may be performed. Pre-conceptual design calculations may be performed while the items 1 through 5 activities are underway—however, the calculated results must be used with judicious engineering judgement.

## **9.2 Economics, Human Factors, PRA, and Other Tools**

The tools used to perform economic evaluations, human factors, plant risk assessments, and other related analyses are in general methodologies that are well known and accepted. The final results are determined not only by the methodology, but also assumptions and weighting factors that are used by the analyst. Consequently, these tools, while requiring review and rigorous quality assurance practices, will not require the validation and development of the systems design and licensing tools. A detailed System Design R&D Plan will be developed during the Project Initiation Phase that will provide a detailed breakdown of activities, cost and schedule for this area of NGNP R&D work.

## **10 MATERIALS AND COMPONENTS**

The objective of the NGNP Reactor Materials Program is to provide the essential materials selection and qualification activities needed to support the design of the reactor and balance of plant. The original objective of the materials program was to initiate materials test irradiations, long term testing (e.g. creep), materials codification activities and provide preliminary materials information and trade-off studies as early in the project as possible in order to support the design process. Due to inadequate funding, these objectives will not be met in FY-04. A direct relationship exists between the materials program and reactor system design requirements. Therefore a delay in the materials program will cause a year for year delay in the design program.

The NGNP materials program will perform all material identification, selection, testing, and qualification activities required to support the NGNP Reactor Project, as following:

- Development of a specific program plan for managing the selection and qualification of all component materials required for the NGNP
- Identification of specific materials for each system component
- Evaluation of the needed testing, ASME Boiler and Pressure Vessel code work, and analysis required to qualify each identified material
- Preliminary down-selection of component materials based on known requirements, manufacturability, and feasibility of achieving needed code licenseability
- Specification and purchase of representative materials for testing
- Design/construction of capsules and vehicles for irradiation of materials where irradiation test data is required

- Performing irradiation of needed sample materials
- Physical, mechanical, and chemical testing of irradiated and un-irradiated materials as required to provide the data to qualify the material for the specific components
- Documentation of materials test data for use by reactor designers and to support required codification for ultimate reactor licensing
- Documentation of final materials selections in support of the design function.

The materials program will address the NGNP reactor, power conversion system, intermediate heat exchange (IHX) system, and associated balance of plant.

This includes:

- The reactor pressure vessel system
- Reactor metallic and composite internals
- Reactor graphite
- Intermediate heat exchanger, piping and pressure vessel
- Hot duct liner and insulators
- Power conversion turbine, compressors and generator
- Power conversion recuperators
- Valves, bearings and seals

Inclusion of materials for hydrogen production will be determined later. As an integral part of the reactor project, the NGNP materials program must interface directly with the reactor design and component specification efforts in an iterative process of component requirements refinement and materials applicability considerations leading to final selection of needed materials.

Specific details of the materials selection and qualification program are documented in the *Materials Selection and Qualification Program Plan, INEEL/EXT-03-01128, November 2003*. This plan will be updated annually while materials program activities are on-going to reflect adjustments in the design requirements basis and their effect on the scope of the materials selection and qualification activities.

## **10.1 Materials Selection Logic**

Materials selection and qualification requires the application of a logical process of determining the most appropriate material for a given component application and obtaining the data necessary to demonstrate that the material can be used successfully. Materials selection requires a specific logical methodology to qualify the material to be used in a component application for the NGNP reactor or balance of plant. This methodology must adequately incorporate the following components and be accepted by the reactor designer:

- Technical acceptability
- Manufacturability
- Cost
- Schedule
- Codification/certification.

If an existing material cannot be identified for an essential reactor component, the decision must be made to either develop such a material or adjust reactor requirements/design to eliminate the issue. Materials R&D/alloy design activities will support the material selection process where existing materials are determined to be incapable of meeting absolute reactor system requirements (such as temperature and pressure), or where significant improvement in material performance is thought possible with a reasonable expenditure of resources (time and money).

The selection process will involve the following sequential steps:

1. Establishment of the Technical Requirements – The service requirements for component materials must be established as the first step in the selection process. The NGNP Reactor Project and its design contractor are ultimately responsible for defining material requirements. Where detailed design information is not available, the selection process may proceed only to the extent that the NGNP Reactor Project can bracket the range of materials requirements expected for any given component.
2. Identification of the Potential Candidate Materials – This process itemizes the potential candidate materials for component construction based on known use requirements and boundary conditions. The listing of candidates could include any number of alloys, ceramics, or other materials as appropriate. A NGNP materials planning working meeting was held July 8-9, 2003 to initially review candidate materials and begin the qualification requirements identification process.
3. Preliminary Selection – This process focuses on a given component or group of related components from the reactor or balance of plant system with the purpose of beginning the process of material selection and itemizing the logic involved in getting to a final selection. This process will result in a document that provides the technical basis for preliminary materials selection and justifies the materials testing program by component. This process will be initiated before the start of testing and will be updated as necessary as the design and materials test information dictate. If preliminary selection identifies three or four materials for qualification testing, an initial scoping phase of qualification testing will then be used to narrow the list down to the two prime candidates. Scoping tests will also be performed as needed to provide early feasibility input required to assist in the selection of component design alternatives.
4. Materials Qualification Testing – This process included generation of the specific test data, codes and standards certifications, manufacturability tests and validations needed to demonstrate that a material can be used without restriction in a specific application within an NGNP reactor that will be licensed by the

NRC. As part of materials qualification and testing, a qualified database with associated empirical correlations will be maintained by the NGNP materials program.

5. Final Selection – This process results in the identification of a single material that has been identified and qualified for constructing a reactor or balance of plant component.

A final materials selection report, which documents the final selection of a material for a given application in the NGNP reactor or balance of plant, will be prepared following the completion of the qualification process. The report will contain a record of the acceptance of any existing data usable for design input and used in qualification, all qualification data generated in support of the selection and usable for design input, manufacturability validation and approved vendors, code status and acceptance, material cost information, and expected lead time required for component construction. Interim topical reports on individual qualification program elements will be generated during the qualification process to provide initial data to the design process and mark completion of interim milestones within the overall program. This selection process is shown graphically in Figure 10-1. The scheduler interface between the primary materials program elements and the other NGNP Reactor high level program elements is shown graphically in Figure 8-1

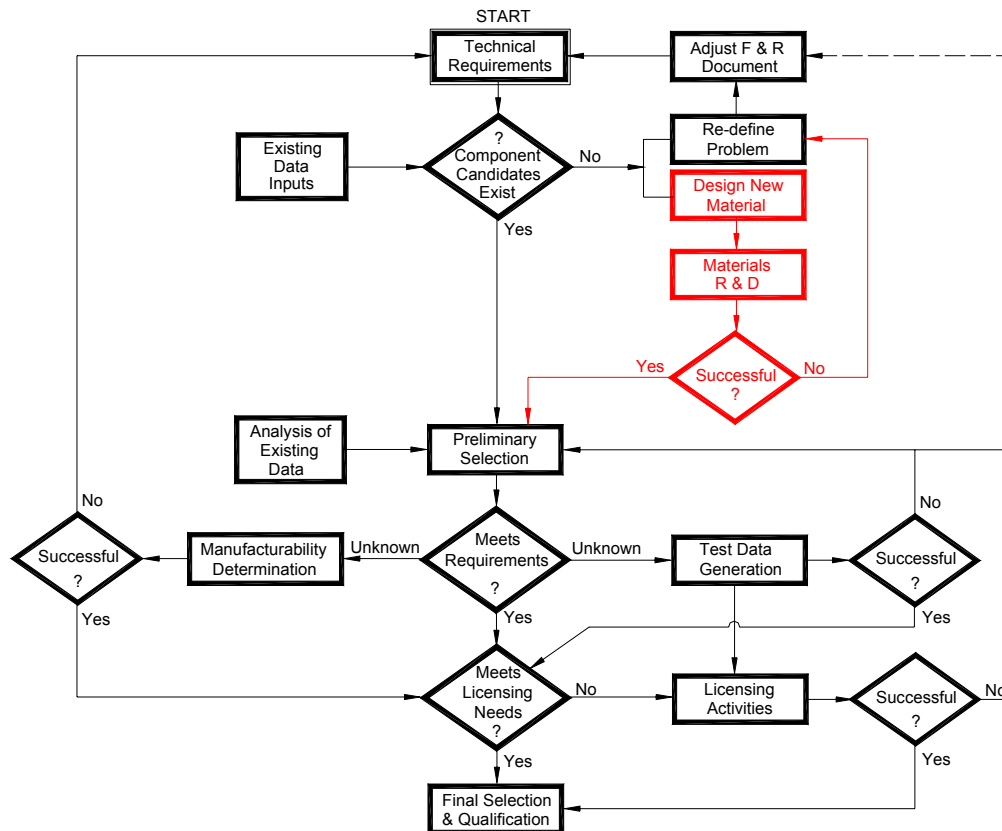


Figure 10-1. Materials Selection Logic Flow Diagram

## 11 ENERGY CONVERSION

### 11.1 Hydrogen Production Technologies

Most hydrogen production methods do not depend on fossil resources to split water molecules using thermal or electrical energy since decomposition of water takes significant energy. Assuming no ohmic losses, about 123 mega joules (MJ) is required to produce one kilogram (kg) of hydrogen. (The energy content of 1 kg of hydrogen is approximately equal to one gallon of gasoline). Direct thermal decomposition of water (thermolysis) requires extreme temperatures of 2500°C or more. Furthermore, current technology to produce hydrogen with radiolysis (i.e., the chemical decomposition of water by the action of radiation) does not meet minimum efficiency requirements for large-scale applications. To address these issues, the R&D strategy for hydrogen production technologies is focused on the following three key areas of development:

- S-I Process Development – Although research is being conducted on techniques to reduce the temperature required for thermolysis and other possible production approaches, the most promising methods using nuclear energy are based on electrolytic or thermochemical processes. To identify the most promising hydrogen production options, available information on thermochemical cycles, high-temperature electrolysis, and other possible production methods was reviewed, and limited confirmatory analyses were performed. Processes were evaluated using general evaluation criteria based on performance potential and demonstrated technical viability. These criteria are also part of the ongoing systematic reevaluation of process potential based on R&D results.
- Technology Assessment – Since all nuclear hydrogen production approaches being considered in the NHI avoid the production of Green House Gases (GHGs) and can be based on domestic resources, the primary issue for nuclear hydrogen is the development of cost-effective systems that produce hydrogen at a cost that is competitive with gasoline. Projecting costs for technologies at this early stage of development is highly uncertain for any of the approaches being considered. The criteria to be used to evaluate the benefits of the various hydrogen production methods to meet these cost objectives include (1) the system and performance characteristics that drive costs, and (2) the uncertainty of the projected costs.
- Process Demonstration Strategy – Demonstrating nuclear hydrogen production by 2016 will require that candidate process information be sufficiently complete to provide an adequate basis for decisions on the next stage of demonstration. To ensure that enough information is available to make the necessary decisions, a systematic demonstration strategy has been developed to allow the maximum amount of flexibility to reassess the priority and promise of process technologies while still ensuring that the overall goal is met. The production process options identified in this Nuclear Hydrogen R&D Plan are currently in different stages of development. Baseline processes are closer to demonstration than are the alternative processes. However, all potential processes will develop in a similar sequence, beginning with the demonstration of viability on a laboratory-scale.

A summary of the activities and sequence for the development of hydrogen production technologies is shown in Figure 11-1. Specific details regarding each of these activities are documented in the *Nuclear Hydrogen R&D Plan*, published in September 2003.

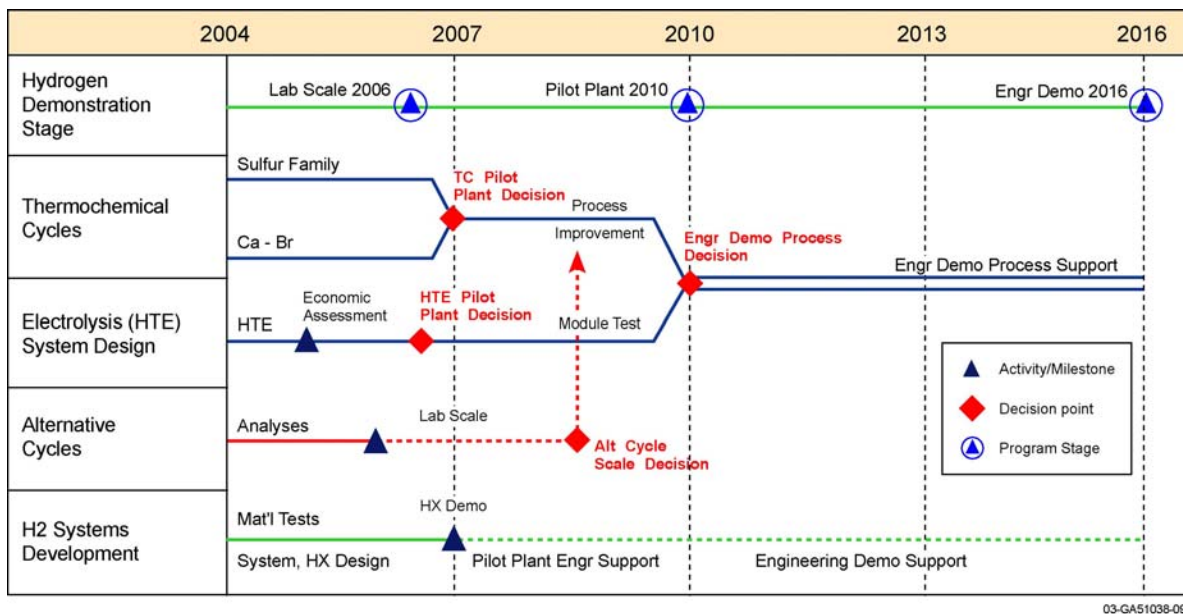


Figure 11-1. Summary of Nuclear Hydrogen R&D Plan Activities and Sequence

## 11.2 Energy Conversion and High Performance Helium Turbine

The pre-conceptual design, proposal, design selection, design implementation, and manufacturing of the required high performance helium turbine(s) are activities that must be centered on the selection and interaction with a qualified manufacturer. Until the design is completed, INEEL researchers can model the presence of the required turbine using assumptions based on the system design specifications.

Because the high performance helium turbine technology knowledge base and manufacturing base are esoteric and require state-of-the art manufacturing techniques, the systems engineering procedures used to select a manufacturer and to subsequently work with the selected manufacturer must be tailored to work with this unique combination. A detailed High Performance Turbine R&D Plan will be developed during the Project Initiation Phase that will provide a detailed breakdown of activities, cost and schedule for this area of NGNP R&D work.

## 12 FUEL DEVELOPMENT AND QUALIFICATION

Development and qualification of TRISO-coated LEU fuel is a key research and development activity associated with NGNP. Kernel fabrication, coating, compacting at commercial scale, and irradiation and accident testing are required to qualify TRISO-coated fuel. The ultimate goal of this R&D program is to successfully demonstrate that TRISO-coated fuel can withstand the high-temperatures, high-burnup and radionuclide confinement requirements of the NGNP. In addition, the commercialization of the fuel fabrication process to achieve a cost-competitive TRISO-coated particle fuel

manufacturing capability to reduce entry-level risks represents a primary goal for the fuel program. A detailed Fuel Development Plan has been developed, which provides a detailed breakdown of activities, cost and schedule for this area of NGNP R&D work. Partnering laboratories, and others as appropriate, will develop R&D Plans that tier from requirements defined in the *Technical Program Plan for the Advanced Gas Reactor Fuel Development and Qualification Plan*, ORNL/TM-2002/262, and perform the portions of work that are assigned to them.

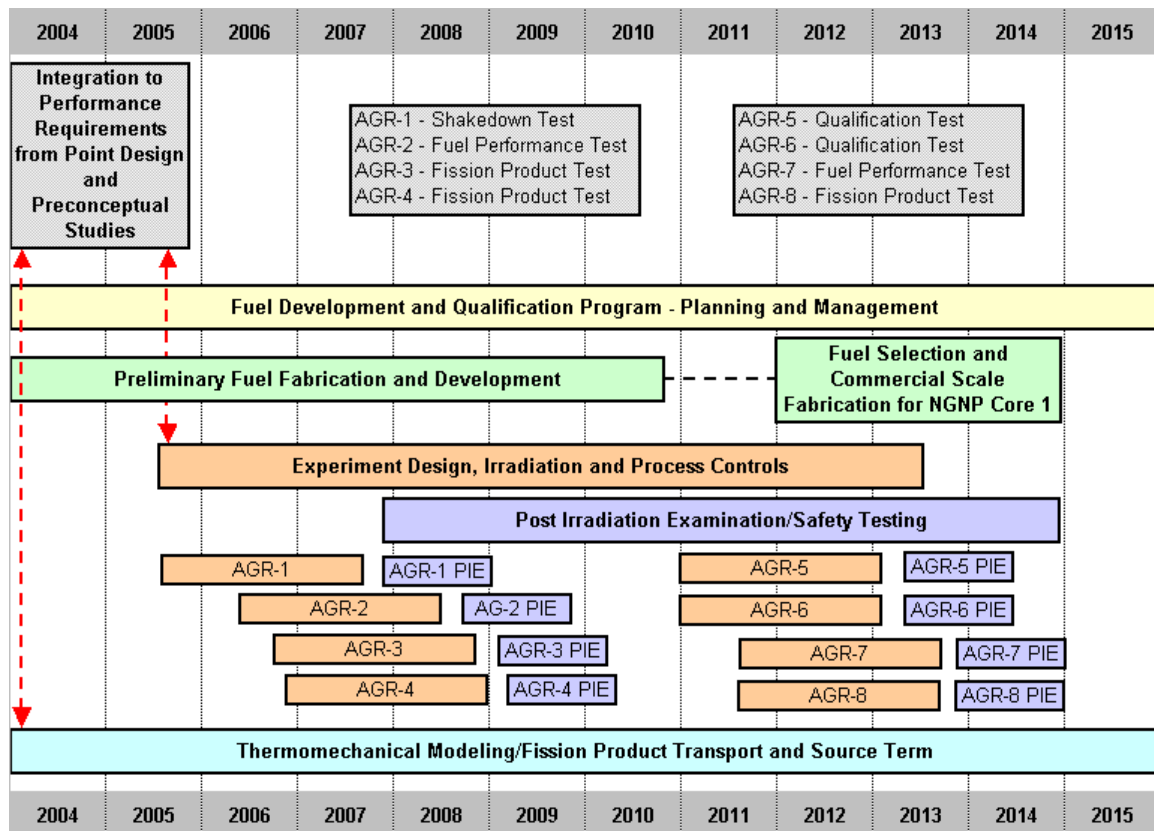


Figure 12-1. High-Level Fuel Development and Qualification Schedule

The NGNP Fuel Development and Qualification Program consists of five elements:

- **Fuel Manufacture** – This element addresses the work necessary to produce coated-particle fuel that meets fuel performance specifications and includes process development for kernels, coatings, and compacting; quality control (QC) methods development; scale-up analyses; and process documentation needed for technology transfer. This effort will produce fuel and material samples for characterization, irradiation, and accident testing as necessary to meet the overall goals. There will also eventually be work to develop automated fuel fabrication technology suitable for mass production of coated-particle fuel at an acceptable cost; that work will be conducted during the later stages of the program in conjunction with co-sponsoring industrial partners.

- Fuel and Materials Irradiations – The fuel and materials irradiation activities will provide data on fuel performance under irradiation as necessary to support fuel process development, to qualify fuel for normal operation conditions, and to support development and validation of fuel performance and fission product transport models and codes. The irradiations will also provide irradiated fuel and materials as necessary for post irradiation examination (PIE) and ex-core high-temperature furnace safety testing. A total of eight irradiation capsules will be used to provide the necessary data and sample materials.
- Safety Testing and PIE – Data from PIE and safety testing will supplement the in-reactor measurements [primarily fission gas release-to-birth ratio (R/B) measurements] as necessary to demonstrate compliance with fuel performance requirements and support the development and validation of computer codes. This work will also support the fuel manufacture effort by providing feedback on the performance of kernels, coatings, and compacts.
- Fuel Performance Modeling – Computer codes and models will be further developed and validated as necessary to support fuel fabrication process development and plant design and licensing. The fuel performance modeling will address the structural, thermal, and chemical processes that can lead to coated-particle failures. The models will not address the release of fission products from the fuel particle, although they will model the effects of fission product chemical interactions with the coatings, which can lead to degradation of the coated-particle properties.
- Fission Product Transport and Source Term – The transport of fission products produced within the coated particles will be modeled to provide a technical basis for source terms for advanced gas reactors under normal and accident conditions. The design methods (computer models) will be validated by experimental data, as necessary to support plant design and licensing.

### 13 QUALITY ASSURANCE

The NGNP Program will use the U.S. national consensus standard ASME NQA-1-1997, “*Quality Assurance Requirements for Nuclear Facility Applications*,” and Subpart 4.2 of ASME NQA-1-2000, “*Guidance on Graded Application of Quality Assurance (QA) for Nuclear-Related Research and Development*” for project-specific development R&D activities. The term R&D is defined as those activities that are scientific in nature and result in the advancement of knowledge or development of technology and their supporting activities.

The NGNP Quality Assurance Program will be based on the principle that quality is the responsibility of management at all levels in the program; and quality shall be planned into all work activities by all program participants. The Lead Quality Engineer shall be responsible for the *development* of the Quality Assurance Program and the independent verification of quality for the program.

The Quality Assurance requirements for specific-tasks, such as the NGNP R&D activities, should be specified in program-specific QAPs and program-specific Technical Specifications. The program-specific QAPs will include the management controls commensurate with the program work scope and importance to the Generation IV Program goals and objectives.

A suggested QAP hierarchy is shown in Figure 13-1 starting with the top-level requirement document DOE O 413.3, "Program and Project Management for the Acquisition of Capital Assets" and in descending order the lower tier management controlling documents dealing with the recommended quality assurance requirements.

Examples of the application of a graded approach of the NQA-1 methodology as it applies to NGNP R&D are as follows:

- Materials R&D use in the NGNP
- Materials R&D that may or may not be used for another concept, e.g., the GFR
- Validation matrix for software to be used for analyzing key safety phenomena in any of the Generation IV reactor systems
- Defining an experimental program to study important safety phenomena in one or more of the concepts
- NGNP Fuel Qualification and Development program using coated fuel particles that could possibly be processed at several different locations
- Irradiation of coated fuel particles by Department of Energy laboratory reactors for the performance of Post Irradiation Exams (PIE) to determine the Proof of Coating Process
- Transfer and use of feed stock materials being supplied from Department of Energy laboratory locations
- Consulting services supplying information for INL Point Design activities.

When the NGNP R&D phase begins the development of design specifications to be used in the title design phase of construction, the NGNP Quality Assurance Requirements document should require full compliance to ASME NQA-1-1997 Part 1 and Subpart 2.7 as well as the ASME Construction Code Section III "Nuclear Power". This will also involve the preparation and submittal of a license application request to the NRC to begin the construction phase activities and the application of 10 CFR 50 Appendix B "Quality Assurance", which is the NRC licensing quality assurance requirements for both a Part 50 or Part 52 license, by the Generation IV program. At the time of NRC license application the Generation IV Program should make a decision to either continue to use the 1997 version of NQA-1 or chose to use the latest issued edition of the NQA-1 Standard which is currently 2000 and by the end of this calendar year it will be the 2003 edition. This will be largely determined by the NRC's position on accepting the latest version of NQA-1 the 1997 NQA-1 has generally been accepted by NRC as fulfilling the requirements of 10 CFR 50, Appendix B. The final Quality assurance approach will be documented by the M&O in a Topical Quality Assurance Program Plan and approved by the USNRC.

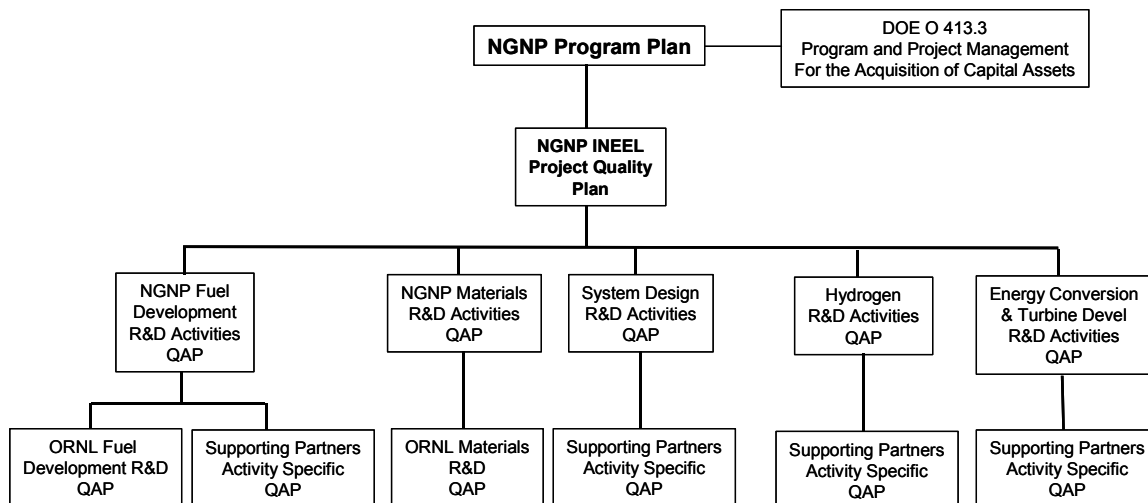


Figure 13-1. Quality Assurance Plan (QAP) Hierarchy

## 14 FY 2004 WORK SCOPE

Major milestones during FY 2004 are listed below. The starred item is the major performance measure. The funding levels and responsible organizations for the FY 2004 work are shown in Table 1.

FY 2004 milestones:

- Issue Revision 0 of the NGNP Materials Selection And Qualification Program Plan - INL
- Issue Requirements section of the NGNP Materials Selection and Qualification Program Plan - INL
- Update the NGNP F&Rs to include Requirements for NGNP Systems Design Models - INL
- Issue Final Independent Technology Review Report – INL
- Issue Draft NGNP Quality Assurance Plan - INL
- Submit Updated Draft NGNP Program Plan approximately 2 months after the INL Site RFP is issued. - INL
- Submit Materials Review Committee review report of NGNP Materials Plan - INL
- Issue the System Design and Evaluation Methods Research and Development Plan - INL
- Prepare NGNP fuel specification and conduct associated core design, neutronics and thermal-hydraulic calculations. – INL
- Fabricate fuel particles for AGR-1 – INL /BWXT
- Complete Preliminary Design for AGR-1 Experiment - INL
- Issue revised (Revision 1) Material Qualification and Selection Program Plan – INL and ORNL
- Award contract for preconceptual design of the NGNP – NE-ID

- Complete draft ORNL NGNP Materials QA Plan – ORNL
- Complete irradiation and storage of graphite scoping capsules – ORNL
- Prepare design materials for the salt-cooled AHTR to be used in making program decision and evaluations - ORNL

**Table 1 Summary of Level 4 Funding for FY 2004 by Performer (\$K)**

<b>Task</b>	<b>INEEL</b>	<b>ORNL</b>	<b>ANL</b>	<b>NE-ID</b>	<b>UNIV</b>	<b>NE-HQ</b>	<b>FY-04 Total</b>
Reactor Design Methodology							
Materials							
Energy Conversion							
Project Management & Support							
Independent Technical Review							
Preconceptual Studies							
Fuel Development							
<b>TOTAL</b>							

## **15 PERFORMANCE MEASURES FOR FY 2005 THROUGH FY 2013**

Major milestones during the 9-year period FY 2005 through FY 2013 are listed below. The starred items are the major performance measures. The budget to support these “required” activities on a normal project schedule is presented in Table 2 below. If this program is funded at the “target” budget levels (5.5 to 15 million per year) a completely different program than discussed here will need to be developed. That program would not result in the construction of a demonstration plant, but rather be focused on fuels development with some smaller amounts on selected key materials and energy conversion technology research activities. For information the expected “Target” level funding for FY-05 is presented after the “required” funding profile shown in Table 2.

FY 2005 milestones (The starred items are the major performance measures):

- Complete Preconceptual Design Studies
- Initiate planning for NRC Construction Permit
- Initiate EIS
- Issue Revision 2 of Materials Qualification and Selection Program Plan
- Prepare and Issue Materials Program QA Plan
- Prepare and Issue Material Review Committee Reports

- Issue Preliminary NGNP Components Materials Selection Reports
- Issue Materials Qualification Testing Program Plan
- Issue ASME Codes and Standards Materials Development Program Plan
- Issue ASTM Materials Development Program Plan
- Issue US Materials Programs Collaboration Program Plan
- Issue International Materials Programs Collaboration Program Plan
- Complete Fabrication and Assembly AGR-1 Experiment
- Fabricate LEU UCO kernels for AGR-2, 3, 4
- Define the Phenomena Identification Ranking Table (PIRT) for the NGNP tools.
- Select the thermal-hydraulic & neutronics tools to be used for NGNP analyses.

#### FY 2006

- Complete Mission Need Statement
- Complete Conceptual Design Plan
- Develop Risk Analysis Plan
- Develop Systems Engineering Plan
- Initiate Permitting work
- Complete Independent Project Review
- Complete Conceptual Design F&ORs
- Complete Conceptual Design Statement of Work
- Submit CD-0 Package for Approval of Mission Need
- Continue NEPA process and EA
- Continue NRC Construction Permitting
- Initiate Preliminary Project Execution Plan
- Issue Materials Qualification Testing Progress Reports
- Issue Revision 3 of Materials Qualification and Selection Program Plan
- Issue Fabrication Infrastructure Development Program Plan
- Prepare and Issue Material Review Committee Reports
- Issue Revisions to NGNP Components Materials Selection Reports
- Issue Materials Program Progress Reports
- Begin AGR-1 Irradiation
- Complete 6" Coater scale-up Design and Testing
- Continue definition of the Phenomena Identification Ranking Table (PIRT) for the NGNP tools.
- Continue selection of the thermal-hydraulic & neutronics tools to be used for NGNP analyses.
- Define the data available to enable validation & verification (V&V) analyses of NGNP tools to be performed.
- Define the experimental needs to enable the NGNP tools to be qualified.
- Release experimental specifications for potential NERI projects to obtain V&V data for NGNP.
- Begin V&V calculations of thermal-hydraulics/neutronics tools.
- Complete evaluation of H<sub>2</sub>/nuclear plant interface modeling requirements report.
- Complete conceptual design evaluation report.

- Complete Phase I V&V of thermal-hydraulic and neutronics tools for NGNP.
- Complete Phase I experimental program for NGNP (simple separate effects experiments that can be done at universities).
- Define integral experiments that must be done to satisfy V&V needs.

#### FY 2007

- \*Complete conceptual design
- Finalize acquisition strategy
- Complete Hazards Analysis
- Complete Value Engineering Plan
- Complete project risk analysis
- \*Complete Project Execution Plan
- Complete Design Requirements Document
- Complete Scope of Work for Preliminary Design
- Continue NEPA process and EA
- Continue NRC Construction Permitting
- Submit CD-1 Package for Approve Requirements, Alternative Selection & Cost Range
- Initiate NRC Pre-licensing process
- Issue Materials Qualification Testing Progress Reports
- Issue Revision 4 of Materials Qualification and Selection Program Plan
- Prepare and Issue Material Review Committee Reports
- Issue Materials Program Progress Report
- Issue Final Materials Qualification Selection Documents for selected components
- Issue NRC Materials Licensing Issues Status Report
- Issue Materials Life Prediction Modeling Status Report
- Fabricate fuel particles for AGR-2,3,4
- Complete Fabrication and Assembly of AGR-2 Experiment
- Complete Phase II V&V of thermal-hydraulic and neutronics tools for NGNP.
- Complete Phase II experimental program for NGNP (separate effects experiments that can be done at universities).
- Build integral experiments to satisfy NGNP V&V requirements.
- Complete Phase I evaluation calculations of preliminary design..

#### FY 2008

- \*Complete NEPA and EA process
- Begin Preliminary Design
- Initiate Preliminary Safety Analysis Report
- Continue NRC construction permitting
- Issue Materials Qualification Testing Progress Reports
- Issue Revision 4 of Materials Qualification and Selection Program Plan
- Prepare and Issue Material Review Committee Reports
- Issue Materials Program Progress Report

- \*Issue Final Materials Qualification Selection Documents for selected components
- Issue NRC Materials Licensing Issues Status Report
- Issue Materials Life Prediction Modeling Status Report
- Begin AGR-2 Irradiation
- Initiate PIE for AGR-1
- Complete Fabrication and Assembly of AGR-3 Experiment
- Update PIRT to match preliminary design.
- Complete Phase II evaluation calculations of preliminary design.
- Complete Phase III V&V of thermal-hydraulic and neutronics tools for NGNP.
- Complete Phase III experimental program for NGNP (separate effects experiments that can be done at universities).
- Continue integral experiments to satisfy NGNP V&V requirements
- Perform calculations for PSAR

#### FY 2009

- \*Complete Preliminary Design
- Complete Independent Cost Estimate
- Complete Independent Project Review
- Submit for CD-2 Approval, Approve Performance Baseline
- Initiate Final Detailed Design
- Submit for "Partial CD-3 Approval" to allow long lead equipment procurement
- \*Manufacture qualification fuel and initiate fuel qualification irradiation
- Complete long term materials tests and finalize materials program
- Continue NRC construction permitting
- Issue Materials Qualification Testing Progress Reports
- Issue Revision 4 of Materials Qualification and Selection Program Plan
- Prepare and Issue Material Review Committee Reports
- Issue Materials Program Progress Report
- Issue Final Materials Qualification Selection Documents for selected components
- Issue NRC Materials Licensing Issues Status Report
- Issue Materials Life Prediction Modeling Status Report
- Complete Fabrication and assembly of AGR-4 Experiment
- Begin AGR-3 Irradiation
- Complete Phase I qualification of thermal-hydraulic and neutronics tools for NGNP.
- Complete Phase IV experimental program for NGNP (separate effects experiments that can be done at universities).
- Continue integral experiments to satisfy NGNP V&V requirements

#### FY 2010

- Continue Final Design
- Initiate long lead equipment procurement (e.g. IHX, vessels)
- Continue NRC Construction permitting

- Issue Materials Qualification Testing Progress Reports
- Issue Revision 5 of Materials Qualification and Selection Program Plan
- Prepare and Issue Material Review Committee Reports
- Issue Materials Program Progress Report
- Issue Final Materials Qualification Selection Documents for selected components
- Issue NRC Materials Licensing Issues Status Report
- Issue Materials Life Prediction Modeling Status Report
- Begin Irradiation of AGR-4
- Initiate PIE for AGR-2
- Update PIRT based on final design specifications.
- Complete integral experiments to satisfy NGNP V&V requirements.
- Complete Phase II qualification of thermal-hydraulic and neutronics tools for NGNP.
- Define final audit calculational needs for NGNP.

#### FY 2011

- \*Complete Final Design
- Continue Long-Lead Procurements
- Update Project Execution Plan
- Submit for Approval of CD-3, Approve Start of Construction
- \*Complete NRC Permit to Construct
- Issue Materials Program Progress Report
- Issue Final Materials Qualification Selection Documents for selected components
- Issue NRC Materials Licensing Issues Status Report
- Issue Final Materials Selection Report
- Initiate PIE for AGR-3
- Validate PADLOC Code
- Complete Phase III qualification (final) of thermal-hydraulic and neutronics tools for NGNP.
- Complete Phase I final audit calculations of NGNP design.

#### FY 2012

- Start Construction
- Integrate Project Schedule and Sub-tier schedules
- Initiate Final Safety Analysis Report
- Initiate NRC Operating Permitting
- Monitor Manage plant construction (subject to final acquisition strategy)
- Continue Long-Lead Procurements
- Issue ASME Codes and Standards Materials Development Progress Report
- Issue NRC Materials Licensing Issues Status Report
- Initiate PIE for AGR-4
- Fabricate fuel particles for AGR-5,6,7,8
- Validate POLO Code
- Complete Phase II final audit calculations of NGNP design

- Initiate FSAR calculations.

#### FY 2013

- Continue plant Construction
- Continue Long-Lead Procurements
- Continue Final Safety Analysis Report
- Continue NRC Operating Permitting
- Issue ASME Codes and Standards Materials Development Progress Report
- Issue NRC Materials Licensing Issues Status Report
- Complete Fabrication and assembly of AGR-5, 6 Experiments
- Begin Irradiation of AGR-5, 6
- Complete Phase III final audit calculations of NGNP design
- Continue FSAR calculations.

### 16 FUNDING PROFILE

Funding table below shows FY-03 & 04 at actual funding. FY-05 provides both Target and Required funding levels. The remaining years are shown assuming that the NGNP will be funded at the level “Required” to efficiently and cost effectively manage the project on a relatively normal schedule. Funding at significantly different levels will extend the project and increase cost.

Table 2 - Summary of VHTR Level 3 Tasks for FY 2005 through FY 2013 (\$M) (Required)